Agricultural IoT System Based on Image Processing and Cloud Platform Technology

Yaxin Zheng(✉) and Chungang Liu

Communication Research Center,
Harbin Institute of Technology, Harbin 150001, China
Asin_zheng@163.com, cgliu@hit.edu.cn

Abstract. Detection of crop disease and growth state have always been the key to ensure the yield and quality of agricultural products. The algorithms, which are in the field of pattern recognition or image recognition, have been using to crop-disease detection and growth-state detection, these algorithms undoubtedly have great significance, and with the development of IoT technology in recent years, the Internet of things technology combining with the existing technology will be the future direction of intelligent agriculture. This paper proposed an agricultural system, which based on the image processing technology and cloud platform of the Internet of things technology. The system can complete image recognition process real-time detection and recording of crop growth status and alarm crop disease in time based on the mutual connection with the cloud platform, and truly realize the unmanned detection in the field of intelligent agricultural system.

Keywords: IoT technology · Cloud platform · Pattern recognition

1 Introduction

China is one of the biggest country of agricultural production, the quality of these production is always people's focus. How to have an effectively detect about the disease and status of crops is the key to producing high quality crops. The disease status of crops can lead to visible changes in the leaves of the crop, and the identification of the crops' surface features can play a role in the detection and prevention of the disease.

The automatic detection of crop growth and disease status can be achieved through a long time real time image recognition process. Therefore, this paper proposes a system based on the cloud platform of the IoT technology and image recognition technology. The system can upload the crop state for a long time and display the crops' status after the process of image recognition to the cloud platform. In this way, we can detect the status of crops remotely through the telephone and websites. In addition, if the system detect the disease about the crops, the cloud platform can send an alarm about it to you immediately. Meanwhile, the system allows you to reverse control some equipments (such as lights, water sprayer, fertilizer application) to improve the environment of the crops in the field (Fig. 1).

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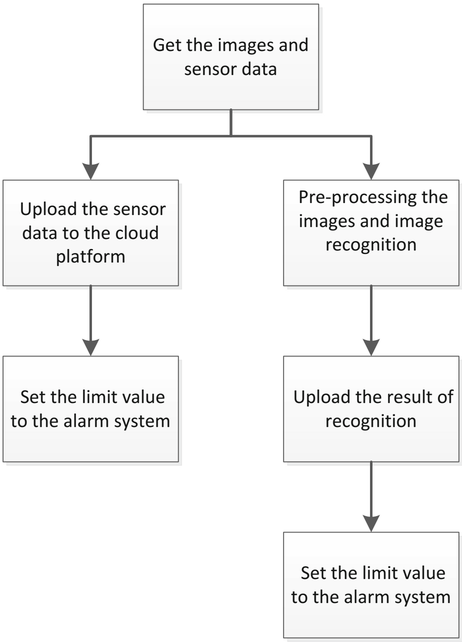

Fig. 1. The working flowchart of the system

2 Basic Process of the System

The system collect the data through the temperature and humidity sensor and the camera that are connected to the self-designed microchip circuit board. About the collected images, we need to use the image processing and get the result of the disease recognition. After that, we transfer the data about the sensors and the recognition results to the cloud platform through the MCU serial. Connect the output of the MCU and the input of the module of WIFI to transfer the data from the MCU to the WIFI module, and then send the data to the cloud platform through RF antenna, along with the connection about the antenna and the wireless router. After the operations about combine the cloud ID with the WeChat or Twitter, we can check the data remotely through the telephone. Moreover, the cloud can periodic send email, text-message and twitter message to the users. During the process of the data transfer, by changing the code about the MCU, we can realize send the sensor-data to the WIFI module successfully and periodic send data to the cloud platform to make sure the users can figure out the real-time situation about the crops and the field.

Then, switch the TCP short connection that we used during send data to the cloud to TCP long connection. In the way of holding the connection about the cloud platform and the MCU and refuse to disconnect it, we can make the cloud to give the orders to communicate with the MCU. So that, we can make the real-time reversal control to come true, to control the equipment in the field as we need.

2.1 The Acquisition of Images and Sensors

The collection of images based on the high-definition cameras, and then transfer the RGB images to HIS images. This color model, which is more close to the color-pattern in human eyes, can make the images more sensitive about the differences between colors and make the recognition more precisely.

About the sensor data, we get it through the temperature and humidity sensors among the field (also we can add any kinds of sensors as we need), this system use the DHT11 sensor to get two different variables, temperature and humidity. The sensor can change the variables to the data that can be upload to the cloud platform; you can just power it to make it work, and no need for other connections to make it more portable.

2.2 Upload Data of Sensors to the Cloud Platform

The design choose STM8 MCU and ESP8266 WIFI module to realize the data transformation. After the register about the cloud platform, we need to set the WIFI module to make sure the module and the cloud are connected. Then, by changing the code of the MCU to initialize the MCU modules and make it to get the sensor data periodically. Every 40 s to make the code into the interrupt routine and send the sensor to the cloud platform.

We have to consider the problems of timer, system clock, and baud rate; so need to set the timer of the MCU to make the system clock into 16 MHz and 128-frequency divider, the baud rate into 115200, enable the timer to make sure it can update the interrupt routine every 40 s.

The DTH11 temperature and humidity sensor used to get the environment data; we should initialize the IO port. To send the sensor data, have to receive the sensor data periodic and put it into the send-buffer. Lastly, recode the interrupt routine to make the MCU send the sensor to the cloud in the format, which the platform needed every 40 s.

2.3 Image Processing, Upload, Reverse Control

2.3.1 Image Processing

The accuracy of image recognition most depends on the pre-operation of the images and the feature extraction. To get a high precision, we used the mixed feature extraction, using color information, texture information, and morphological information to get a mixed feature information. Afterwards, using the SVM to recognize the images, in this way, we can detect the disease crop image.

Because most of the leaves of diseased plants' color will change, so color information is an essential part of the process of crop disease recognition, we can use color information as a part of the feature information. This design uses the color information features as the HSI color mode, that is, we need to converse the images the camera captured. Many cloud platforms have the corresponding image sensors, if the users need; they can save them to the platform. For a given RGB format image, each pixel corresponds to the H (hue) component can be obtained by the following equation, but the component is also needed to be divided by 360° normalized into [0,1] interval.

$$H = \begin{cases} \theta & (B < G) \\ 360 - \theta & (B \geq G) \end{cases} \tag{1}$$

$$\theta = \arccos\left\{ \frac{1/2[(R-G)+(R-B)]}{(R-G)^2+(R-G)(G-B)^{1/2}} \right. \tag{2}$$

S (saturation) and I (intensity) components are expressed as follows, these two components have already been in the [0,1] interval between, so do not need normalization:

$$S = 1 - \frac{3}{(R+G+B)}[MIN(R,G,B)] \tag{3}$$

$$I = \frac{1}{3}(R+G+B) \tag{4}$$

Crop image via HSI conversion results as shown in Fig. 2; we can see that in the case of yellow diseased leaves area after transformation will appear darker effect, thus the conversion mode for effective detection.

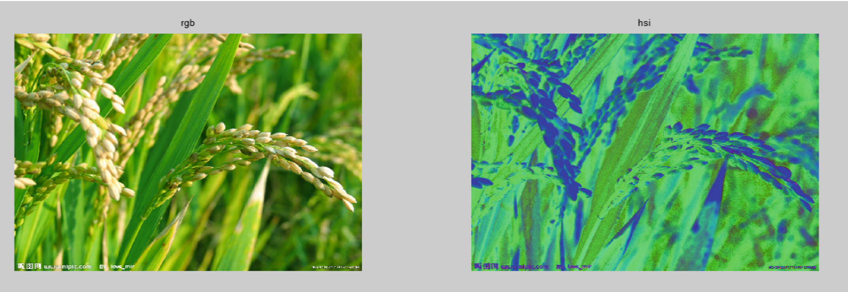

Fig. 2. Images before and after the HIS transformation

If we only do the image recognition with color feature information, the recognize result will cause remarkable error. We figure that the crop disease occurs mostly the short plant and the spots on the leaves, so the texture information and morphological characteristics will also be the significant feature information. To mix these three kinds of information can get a higher accuracy.

All the feature information are getting from the gray level images, and need to process these images to make the information more efficient. In this paper, we use the Laplacian algorithm to sharpen the image, and then, using the Gauss filter to reduce the noise. Lastly, the histogram equalization make the needed information more significant.

The Laplacian operator is used to sharpen the image detail information of the crops, and the detail information of the disease is strengthened, after that, the effectiveness of the identification be improved. In the process of image acquisition and conversion, noise is inevitable. Because the main information of image recognition exists in the low frequency part, we can use the Gaussian filter to reduce the noise, which is almost in the high frequency part, and protect the low frequency part. This method will reduce the effect for the recognize process from the noise. Finally, the image texture features are well distributed by histogram equalization, and the texture image is clearer. The processed gray images were as shown in Fig. 3, and the images show that the processed imaged are obvious more effective than the untreated images in details, effectiveness, and display of gray images.

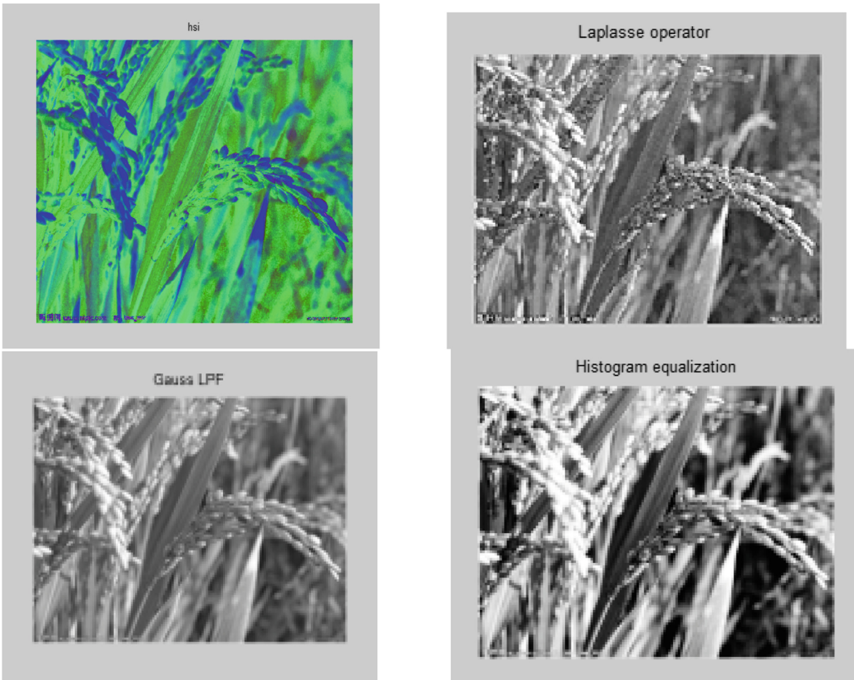

Fig. 3. The images after Laplacian algorithm sharpen the image process, the Gaussian filter process, and the histogram equalization process

Image texture feature obtained by gray level co-occurrence matrix, and save the texture feature vector as the corresponding matrix variables. The acquisition of simple morphological feature vectors are got by simple region descriptors. After obtaining the texture features of the image, the local binary pattern (LBP) is used to reduce the dimension of the texture feature firstly, which can produce the non-one order statistical features of the image structure information. The LBP algorithm is chosen for its superior texture ability, high classification ability and computational efficiency. The results show that the dimension reduction effect is obvious and the overall trend has not changed greatly, so the algorithm can play an important role in improving the utilization rate of resources, as shown in Fig. 4.

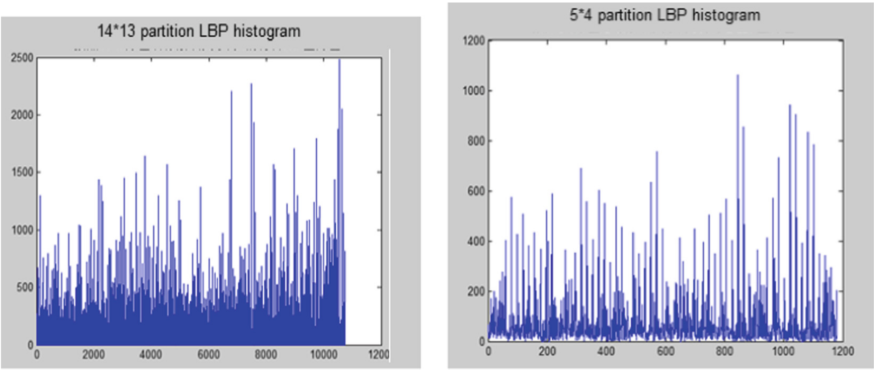

Fig. 4. The results of the dimensionality reduction, the left image shows that the result of 14*13 partition LBP histogram, and the right image shows that the result of 5*4 partition LBP histogram. The left one has more details and the right one has more efficiency.

The three feature vectors are combined to make the recognition process more than just one element, the combination prevent the error caused by the color, shape and other individual phenomena. In the second step of dimensionality reduction, the color feature information, the refined texture information and the morphological feature information will combine with each other and reproduce the new feature information matrix. Because of the high dimensionality of the feature vector and the relative invalid feature, the computing resources are wasted. In this process, we use the PCA algorithm to reduce the dimension of the combined matrix. This is the way to make the result more precisely and the computation more efficient.

After the refined step, which is the reducing dimension part, we use the SVM to train and test the images. The SVM technology based on the principle of structural risk minimization, give consideration to the training error and test error. This algorithm achieve the best classification results by selecting different kernel functions, and using parameter search tools to get the best parameters that we need to used. Also, it is also possible to avoid the over-training phenomenon that the artificial neural network technology has been happened, the SVM makes the classifier after full training has a higher classification effect. Through the acquisition of the image recognition, detection of the current gives the type of disease within the scope, to grasp the disease status of field crops.

2.3.2 Upload the Result of Recognition and Reverse Control

The identified category information is converted to ASCII code and send to the WIFI module through the serial port, WIFI module connected to the cloud platform can send data to it. Because image processing takes a relatively long time, to avoid the connection between the cloud and the WIFI module to released, the MCU can send some initialize value to fill the time. When identifying the disease category, send the designed number to present the disease, in the paper the designed number is 99. When the received number is bigger than the limit value we set on the cloud, the cloud will send the users an alarm to make the users to solve the disease problems.

The reverse control function also need to be realized by the TCP link. Make a connection about the cloud platform and the WIFI module to succeed the send/receive message with the STM8 MCU chip, and get the data at the specific location of a fixed format to control the pin into a low or high level to switch the status about the equipment in the field. In this method, the users can realize change the switch status to control the medicine, fertilize, water. In addition, the cloud not only turn the switch from on to off, but also can control the number controller from 0 to 255.

First, we need to send messages to the cloud platform through MCU chips, so the TCP connection about the cloud and the MCU will be created. After the connection has been created successfully, the MCU will send the register message to the cloud platform, the specific data can change along with the data the users used during the register ID process. Afterwards, the MCU can be coded to waiting the messages, which the cloud send back to the MCU chip. In this way, we can link the cloud ID to the MCU chip, and then, we have to send initialize information to the controller in the cloud when the MCU received the feedback message. In this paper, we decided to set the switch controller to on and the number controller to the number 1. After the operations above, we can set the initial state of the controllers, and then, when we click the controllers in the cloud through websites, the MCU will get different values with the fixed format. If we let the MCU to get data at the specific location, we can get the situation the equipment in the field need to be.

Take the switch controller as an example, if the switch controller were set the controller status to be off, the MCU will get the data 0 from the cloud, we should get the data 0 at the fixed location of the feedback message, and turn the pin PD4 (which we used to control the power of the equipment) to a low-level output to let the power of the equipment in the field to be off. When the data interaction between the cloud and the MCU be stopped for 40 s, the TCP link will released, if need to reverse control after that, should to reconnect it again.

3 Debugging the System

To test if the designed IoT system can truly realize the real-time collection about the crops' situations and complete the reversal control, we need to debug the system. During this experiment, we choose the DHT11 sensor to feel the difference about temperature and humidity. Then, we create the temperature/humidity sensor in the cloud platform; the platform will give your sensor an ID number when you finish the created. The ID number about our DHT11 sensor is 38416, and the data that we upload to the cloud platform are as follows:

```
POST /v1.0/device/21775/sensor/38416/datapoints
HTTP/1.1
Accept: */*
Host: api.yeelink.net
U-ApiKey:6ac5806f65203ce63a7bf39d604ae206
Content-Length: 14
Content-Type: application/json;cahrset=utf-8

{“value”:59}
```

The platform can detect the data of the specified location to find out the temperature or humidity; this is because the format of the sending message is stationary.

When the sensor of cloud platform receive a number which is bigger than the designed limit value, the cloud can send an alarm to the user to make the situation of the crops can be improved. The sensors are not only about the temperature but also can use to send alarms when the crops were detected to be illness. When we need to upload the status of the crops, the created sensors in the cloud platform need to be generic sensors, which we can design the key word to display the status and the value. We designed the code of crops' disease to be 99, and then when the cloud platform received the value of 99, the users will get an alarm about the disease. In this way, the users can be more clearly to figure out the situation about the crops and the field. The data that the generic sensor will upload are as follows:

```
POST /v1.0/device/1/sensor/5/datapoints HTTP/1.1
Accept: */*
Host: api.yeelink.net
U-ApiKey:78195d42-df52-45ca-af5f-70a4c6777ef9
Content-Length: 97
Content-Type: application/json;cahrset=utf-8

{“key”:”shibeiqingkuang”,“value”:{99}}
```

When we need to control the equipment, which is in the field through the cloud platform, we will receive the data the platform send to are as follows:

```
GET /v1.0/device/1/sensor/3/datapoints HTTP/1.1
Host: api.yeelink.net
U-ApiKey:78195d42-df52-45ca-af5f-70a4c6777ef9
Content-Length: 0
Connection: close
```

The realization about the system as show in the figures, you can complete the data upload, check the real-time situation through the App in your phone, periodic send the sensor-data to the platform and use the platform to reverse control. Figure 5 is representing check the uploaded data through website, the WeChat and the website of telephones; and Fig. 6 shows that the website when you want to reverse control the power of the equipments in the field (the red means the switch is off, and when you click it you can change the switch to on).

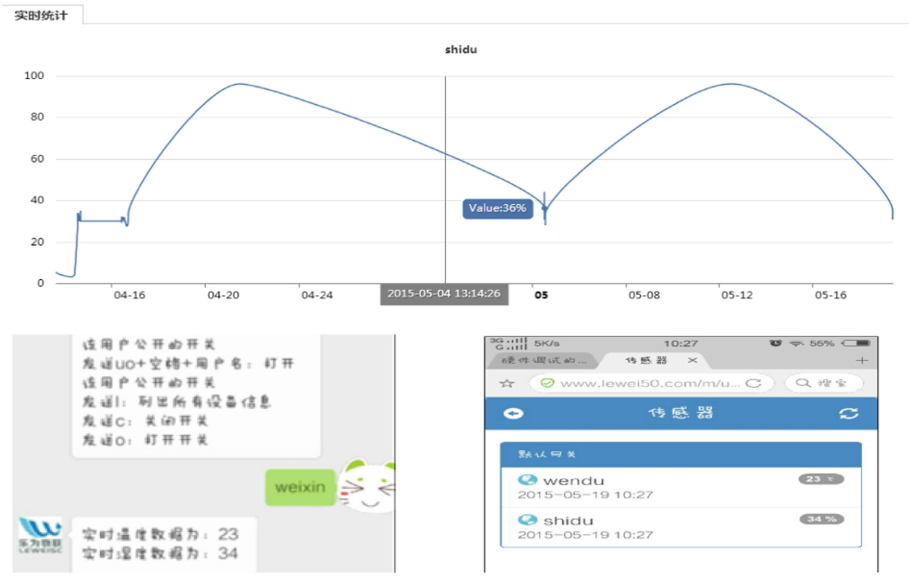

Fig. 5. Display of debugging the IoT system, which is about checking the sensor data in real-time.

Fig. 6. Display of debugging the IoT system, which is about reversing control the equipment in the field

Through the operations of the designed system, we can see that the system can realize the real-time monitor, the reverse control; the data uploaded and display the curve of the changing sensor-data.

4 Conclusion

To satisfy the needs about producing high-quality crops, we need to find out what status the crops are and how to fix the problematic situation in time. The system which the paper purposed realize the real-time control of crop growth environment, real time recognize disease image for the collected crop images and send an alarm about it. Make people can remotely through the mobile client, WeChat, micro-blog to get a full range of real-time understanding check on the growth state and disease situation of the crops. Moreover, can real-time reverse control based on different conditions of the environment that the crops are, so that crops grow more intelligent and flexible.

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